



Analysis of magnetic resonance imaging–confirmed soft tissue injury pattern in simple elbow dislocations

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Background: The elbow is the second most commonly dislocated joint. Stability depends on the degree of soft tissue injury, with 2 proposed patterns, one starting laterally and the other medially. The purpose of this study was to describe the injured structures observed in magnetic resonance images (MRIs) in a prospective cohort of simple elbow dislocations.

Methods: We evaluated 17 consecutive cases of simple elbow dislocations. Two musculoskeletal radiologists assessed the initial x-ray images and MRIs performed for all elbows. Radiologists evaluated the following soft tissue structures: medial collateral ligament complex (MCL), flexor-pronator muscle mass origin, anterior capsule (AC), posterior capsule, lateral collateral ligament complex (LCL), and extensor muscle mass origin. The radiologists were blinded to the study hypothesis.

Results: The initial radiographs in 16 patients showed the dislocation was posterolateral in 12, posterior in 3, and posteromedial in 1. We observed complete AC tear in 12 patients, MCL in 10, and LCL in 9. The inter-rater reliability for the radiologists was 0.70 (substantial) for MRI.

Conclusions: In our series after simple elbow dislocation, complete AC tears were most common, followed by MCL and LCL tears. No single mechanism-related soft tissue injury pattern of simple elbow dislocation was observed, and different grades of soft tissue injury exist.

Level of evidence: Anatomy Study; Imaging
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Keywords: Elbow; dislocation; collateral; ligament; injury; tear; MRI

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The elbow is the second most commonly dislocated joint after the glenohumeral joint.⁶ Simple elbow dislocation is defined as an elbow dislocation without bony injury. The extent of soft tissue injuries might have an effect on the choice of treatment, rehabilitation, and prognosis.^{1,8}

A model has been proposed in which simple elbow dislocations follow a stepwise posterolateral rotatory instability

pattern where elbow extension, valgus, and forearm hypersupination cause sequential disruption of soft tissues originating from the lateral collateral ligament complex, which then, depending on the amount of energy transmitted, continues through the anterior capsule (AC) and posterior capsule (PC) to the medial collateral ligament (MCL) and soft tissue structures (the circle of Horii).^{9,11} The evidence of this theory arises from chronic posterolateral rotatory instability cases and studies in cadavers, and indeed, little is known about the true soft tissue injury distribution of acute simple elbow dislocations.^{9,10}

The purpose of this study was to prospectively evaluate and describe the acute soft tissue injury patterns of a consecutive series of simple elbow dislocation cases based on magnetic resonance imaging (MRI) evaluation. We hypothesized that there is no single mechanism-related soft tissue injury pattern of simple elbow dislocation and that there are a higher number of medial ligamentous injuries with acute simple elbow dislocations.

Materials and methods

Over a 24-month period, 17 consecutive patients with simple elbow dislocations with no concomitant bony injuries presented acutely to a single institution. The mean age was 41.7 years (range, 12–72 years). There were 8 males and 9 females, 15 patients were right-hand dominant, and the dominant side was affected in 8. Patients were treated initially in the emergency care department and went through closed reduction under sedation or general anesthesia. All but 1 had x-ray images of the injured elbow before closed reduction. The elbow in this patient was reduced in an ambulance on the way to the emergency department.

All patients were treated nonoperatively and went through a controlled mobilization program under the care of a specialist physiotherapist. Progress was monitored in the fracture clinic. The mobilization was initiated within 1 week of the injury.

An elbow MRI scan was performed for all patients as soon as practically possible after the injury (mean, 1.6 weeks; range, 0–4 weeks). MRI was performed using Achieva 1.5T (Philips Healthcare; Eindhoven, The Netherlands) and Magnetom Aera 1.5T (Siemens Healthcare Systems AG; Erlangen, Germany) equipment. We used coronal T1, coronal short tau inversion recovery sequence, axial T1, axial proton density fat suppression sequence, sagittal T2, and sagittal proton density fat suppression sequence.

Two musculoskeletal radiologists (DT and SB) assessed the plain radiograph and MRI images first independently and then together. In case of disagreement, mutual consensus was established through negotiation. For the purposes of this study, lateral collateral ligament (LCL) structures—radial collateral ligament, annular ligament, and lateral ulnar collateral ligament—were analyzed as one complex (ie, LCL). Similarly, MCL structures—anterior bundle, posterior bundle, and transverse bundle—were evaluated as one structure (ie, MCL). Radiologists were asked to evaluate the following soft tissue structures: MCL, flexor-pronator muscle mass/common flexor origin (CFO), AC, PC, LCL, and common extensor muscle mass origin (CEO). The radiologists were blinded to the study hypothesis.

MCL, LCL, CFO, and CEO were graded as intact, partial tear, or complete tear. AC and PC were graded as intact or torn. Definition

of partial tear was essentially where there was disruption to the ligament insertion by the presence of fluid signal hyperintensity. Initially, low-grade partial-thickness tears were graded if there were above 10% but less than 50% of fiber disruption, and high-grade partial tears if more than 50% of fibers were disrupted. Both were graded as partial-thickness tears. Complete loss of ligament continuity was graded as a full-thickness tear.

We used the initial radiographs to group the elbows according to the direction of dislocation as (1) posterolateral, (2) posterior/perched, or (3) posteromedial (PM; Fig. 1). The direction was defined from the initial x-ray images. The prevalence of each of the soft tissue injuries (MCL, LCL, CFO, CEO, AC, PC) was compared between the groups and within each group using the Fisher exact test.

We assessed interobserver reliability of MRI and x-ray images by calculating the Cohen κ coefficient among the 2 assessors.

Results

We identified 17 consecutive patients with acute traumatic simple elbow dislocations. The initial radiographs showed 12 patients had posterolateral, 3 had posterior/perched, and 1 had PM dislocation. One patient did not have radiographs before reduction. The demographics, injury mechanisms, and x-ray and MRI findings, are presented in Table I and dislocation patterns in x-ray images in Fig. 1.

When all dislocations were analyzed as a single group, we observed complete tears of AC in 12 patients, MCL in 11, and LCL in 9. Only 2 patients had complete rupture of the CFO or PC. One patient presented with CEO and PC tears in addition to complete tears of MCL and LCL (Fig. 2, A). The larger posterolateral group was analyzed independently. In this more common direction of injury, the frequency of injury seemed to be higher on the MCL compared with the LCL (Fig. 2, B). However, when comparing the prevalence of injury and grade of injury to the MCL, AC, LCL, CFO, and CEO within all dislocations and the posterolateral dislocation group separately, we found no statistically significant differences. Furthermore, patient age, injury side, or the mechanism of injury did not correlate with the type of dislocation.

The soft tissue injury distribution of other than posterolateral injuries is presented in Fig. 2, C and dichotomized soft tissue injury distribution of MCL, LCL, CFO, and CEO in posterolateral dislocation in Fig. 3. The posterolateral dislocation group had a higher prevalence of MCL injuries than the posterior/perched dislocation group ($P = .04$). The difference in other soft tissue injuries between the posterolateral and posterior/perched groups was not statistically significant. There was only 1 patient in the PM dislocation group. The injury pattern was akin to the Horii model, with a worse injury on the lateral side, but making a meaningful analysis is not possible with only 1 case.

The inter-rater reliability was 0.70 for direction of dislocation in the initial radiographs. The inter-rater reliability was 0.70 (substantial) for MRI when findings were graded in 3 grades (intact, partial tear, or complete tear) and 0.70



Figure 1 The simple elbow dislocation directions on plain x-rays: (A) posterolateral, (B) posterior, and (C) posteromedial.

(substantial) when the findings were dichotomized (intact or torn). The inter-rater reliability for evaluation of the direction of dislocation in radiographs before reduction was 0.70 (substantial). The complete and partial tears of different soft tissue structures in MRI scans are illustrated in Fig. 4, A-C.

Discussion

Injury patterns in simple elbow dislocations have been the subject of numerous studies. In the 1980s, Josefsson et al⁵ reported a high incidence of medial-sided injuries in simple dislocations and determined that stable and unstable injuries

were differentiated by the presence of tendon avulsion. They then compared the effect of acute surgical stabilization compared with nonsurgical treatment on recurrent instability and reported no significant differences.⁴ That study, however, failed to stratify the patients from those with more minor soft tissue injuries to those with the most severe.

The classic study by O'Driscoll et al⁹ on chronic elbow instability introduced the concepts of posterolateral rotatory instability and the Horii circle, where there was a pattern of injury that started laterally and passed medially through the AC and PC. The Horii circle model is based on the observation of 5 clinical patients with chronic instability and a subsequent cadaveric study in which the division of

Table I Injury characteristics, x-ray imaging, and magnetic resonance imaging findings of the patients

Patient	Age (yr)	Side of injury	Mechanism of trauma	Direction of dislocation on x-ray images	MCL	CFO	AC	PC	LCL	CEO
1	53	Right/dominant	Simple fall on outstretched hand	Posterolateral	Complete tear	Partial tear	Intact	Intact	Complete tear	Intact (CEO obscured)
2	40	Right/dominant	Simple fall on outstretched hand	Posterolateral	Partial tear	Partial tear	Tear	Intact	Partial tear	Partial tear
3	49	Right/dominant	Simple fall on outstretched hand	Posterolateral	Complete tear	Partial tear	Tear	Intact	Complete tear	Intact
4	63	Left/nondominant	Fall on stairs on outstretched hand	Posterolateral	Complete tear	Complete tear	Tear	Intact	Partial tear	Intact
5	45	Right/dominant	Simple fall on outstretched hand	Posterolateral	Complete tear	Partial tear	Intact	Intact	Partial tear	Intact
6	61	Right/dominant	Simple fall on outstretched hand	Posterolateral	Complete tear	Partial tear	Tear	Tear	Complete tear	Complete tear
7	29	Right/nondominant	Simple fall on outstretched hand	Posterolateral	Complete tear	Partial tear	Tear	Intact	Complete tear	Partial tear
8	72	Right/nondominant	Simple fall on outstretched hand	Posterolateral	Complete tear	Partial tear	Intact	Intact	Partial tear	Partial tear
9	24	Left/nondominant	Simple fall on outstretched hand	Posterolateral	Complete tear	Intact	Tear	Intact	Partial tear	Intact
10	68	Left/nondominant	Fall from 25 cm height on outstretched hand	Posterolateral	Complete tear	Complete tear	Intact	Intact	Complete tear	Partial tear
11	31	Right/dominant	Fall backwards downstairs on outstretched hand	Posteromedial	Partial tear	Intact	Tear	Intact	Complete tear	Partial tear
12	20	Left/nondominant	Tackle injury in rugby	N/A	Complete tear	Partial tear	Intact	Intact	Complete tear	Partial tear
13	14	Left/nondominant	Hyper extension in rugby tackle	Posterolateral	Partial tear	Partial tear	Tear	Intact	Intact	Intact
14	31	Left/nondominant	Simple fall on outstretched hand	Posterolateral	Partial tear	Partial tear	Tear	Intact	Partial tear	Partial tear
15	44	Left/nondominant	Simple fall on outstretched hand	Posterior	Complete tear	Partial tear	Tear	Tear	Complete tear	Partial tear
16	12	Right/dominant	Fall from horse on outstretched hand	Posterior	Intact	Intact	Tear	Intact	Complete tear	Partial tear
17	54	Right/dominant	Fall off monkey bars at 30 cm height	Posterior	Intact	Intact	Tear	Intact	Partial tear	Intact

MCL, medial collateral ligament complex; CFO, common flexor origin; AC, anterior capsule; PC, posterior capsule; LCL, lateral collateral ligament complex; CEO, common extensor origin.

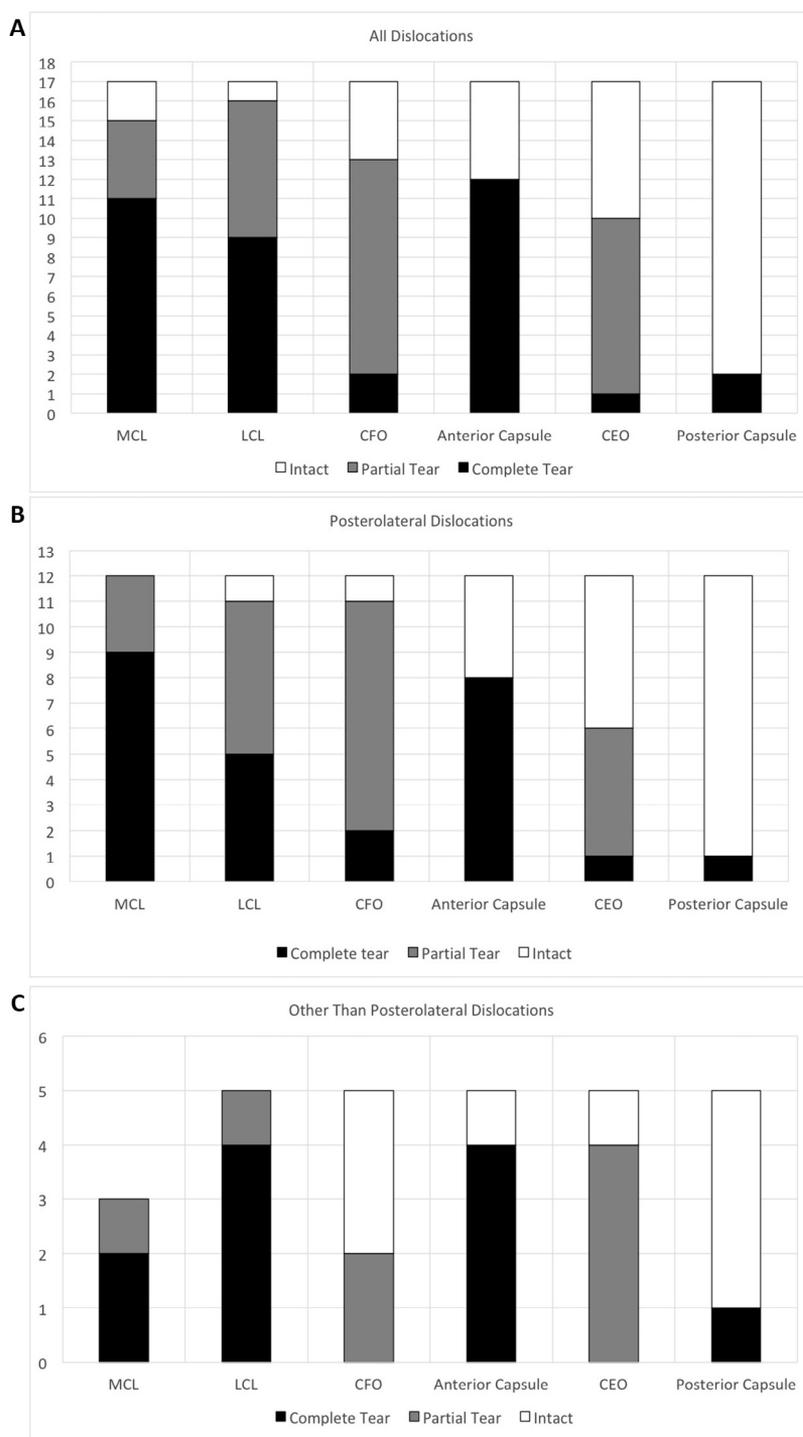


Figure 2 Soft tissue injuries in (A) all dislocations, (B) posterolateral dislocations, and (C) other than posterolateral dislocations. *MCL*, medial collateral ligament complex; *LCL*, lateral collateral ligament complex; *CFO*, common flexor origin; *CEO*, common extensor origin.

capsuloligamentous structures was performed according to the theory.^{9,10} The authors hypothesized that a common mechanism of injury leads to a spectrum of chronic instabilities. A combination of axial load, supination, and valgus moment would result in sequential injury starting from the LCL advancing to PC and AC, which allows the elbow joint to dislocate posteriorly. According to the theory, the MCL is the

last structure to disrupt after the joint is already dislocated. Although this hypothesis was not validated by data from acute elbow dislocations, the proposed 3-stage spectrum of instability nevertheless gained wide acceptance as the sole mechanism of acute simple elbow dislocations.

The authors of a recent study observed video footage of acute elbow dislocations and suggested that most simple elbow

MRI Findings in Posterolateral Dislocations				
MCL	LCL	CFO	CEO	No.
-	-	-	-	3
+	-	-	-	3
+	+	-	-	3
+	+	+	-	2
+	+	+	+	1

Figure 3 Dichotomized soft tissue injury distribution of medial collateral ligament complex (MCL), lateral collateral ligament complex (LCL), common flexor origin (CFO), and common extensor origin (CEO) in posterolateral dislocations on magnetic resonance imaging (MRI).

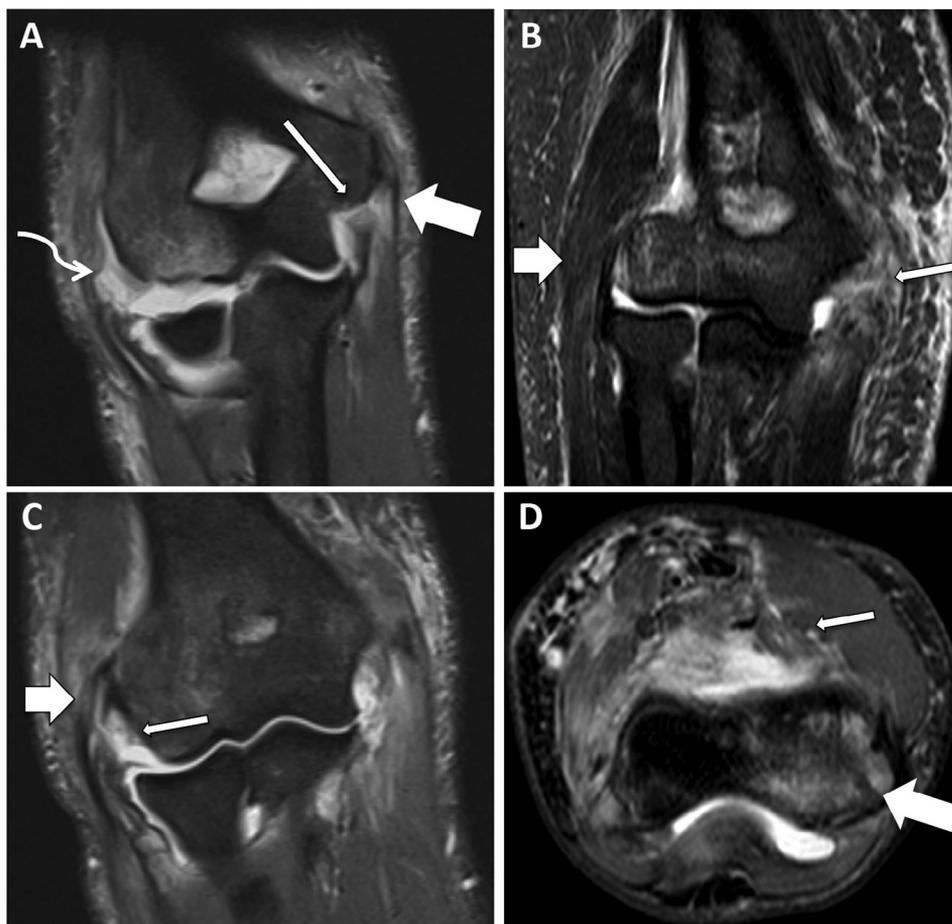


Figure 4 Magnetic resonance images of injured structures. (A) Short tau inversion recovery sequence (STIR) coronal: *narrow arrow*, full-thickness medial ligament tear; *thick arrow*, partial-thickness common flexor origin tear; *curved arrow*, full-thickness lateral ulnar collateral tear. (B) STIR coronal: *narrow arrow*, full-thickness common flexor origin and medial collateral ligament tear; *thick arrow*, intact common extensor origin and intact lateral collateral ligament complex. (C) Proton density fat suppression sequence (PD FS) coronal: *narrow arrow*, full-thickness lateral ulnar collateral tear; *thick arrow*, high-grade partial-thickness common extensor origin tear. (D) PD FS axial: *narrow arrow*, anterior capsular tear; *thick arrow*, lateral humeral condyle bone marrow edema effusion.

dislocations occur with hyperextension and valgus load.¹⁷ Further analysis of MRI scans from 16 acute elbow dislocations showed a higher degree of medial injury compared with the lateral side.¹⁶ The authors hypothesized that the sequential soft tissue disruption could, in fact, start from medial and advance in a lateral direction. However, the retrospective nature of the study meant that only a small proportion of patients in the series had an MRI examination, and there was a risk of selection bias.¹⁶ This study was supported by the observations of Rhyou et al.¹²

The present study suggests that there is more than 1 pattern of soft tissue injury. This variation is likely to be dependent on the direction of forces applied at the time of dislocation, the position of the limb and hand at the point of contact, and variations in the tissue laxity of the patient. Most simple dislocations are posterolateral injuries, as reflected in this study, and the injury pattern in this group appears to initiate on the medial side of the elbow, with all elbows exhibiting a medial ligament injury. A smaller proportion of patients have a lateral ligament avulsion, and the same discrepancy is observed for the common flexor and extensor origins (Fig. 2).

Based on the acute elbow MRI, a potential sequence of injury for posterolateral dislocation can be suggested based on knowledge of the mechanism of injury. As the elbow goes into hyperextension and valgus, the relatively stiff medial ligament fails. As the joint opens further, the lateral ligament, also stiffer than the tendons fails next, then the common flexor origin. Further displacement leads to failure of the AC and then the CEO. The only patient found to have a PC tear in our study was also the only patient with complete disruption of the CEO. The extent of individual injuries is thought to be dependent on the energy expended and the degree of displacement. It seems logical that those with the most extensive injuries are likely to be at the greatest risk of recurrent instability.

Most simple elbow dislocations may be treated nonoperatively by closed reduction, followed by controlled mobilization.^{3,4,7} MRI examination shortly after simple dislocation enables stratification of the injury. Based on the work of Joseffson and the senior author's (ACW) personal experience of manipulation under anesthesia after simple dislocation, patients who exhibit gross instability and are therefore operated on are those with injuries extending to complete avulsion of the CEO. Although this is not proven by the current study, work by Schnetzke et al¹⁴ indicates that acute surgical stabilization results in a superior outcome in those exhibiting moderate or gross instability at early examination under anesthesia. The clinical importance of the soft tissue injury pattern was recently studied by Adolfsson et al¹ in a series of recurrent simple elbow dislocations that were noted to be grossly unstable at the initial examination under anesthesia. They observed that the common feature was associated tendon avulsion, particularly on the lateral side of the elbow.¹

It should be considered that the evidence of the clinical benefits in the use of MRI scan in acute simple dislocations is scarce, and there are concerns regarding the quality and

reproducibility of the interpretation of ligament injuries. Partial tears might be detected with low sensitivity, and the structures that contribute significantly to stability may be poorly visualized in MRI, such as the lateral ulnar collateral ligament.^{2,13,18,20} After acute simple dislocation, the elbow is often held in a semiflexed position due to pain and swelling, restricting extension that does not allow the ligaments to be tensioned and thus makes the interpretation difficult.¹⁹

A recent study noted that for interpretation of ligament injuries after acute dislocation, interobserver agreement was fair to moderate and that intraobserver agreement was slight to moderate.¹⁵ In the current study, however, 2 experienced radiologists performed the comparison. The intraobserver reliability of the radiologists was not assessed in this study. In addition, we note that direction in the x-ray images does not necessarily reflect the true mechanism or direction of the injury, but because the x-rays are performed initially, the classification can serve as a starting point for assessment.

The strengths of this study are that it was a consecutive series of patients, and it was possible to record the initial dislocation direction in all but 1 patient. MRI scans were performed in all patients within a short time after the initial injury. Two experienced subspecialized musculoskeletal radiologists evaluated the data independently, with substantial interobserver reliability when injuries were evaluated in 3 grades or when dichotomized. In addition, the radiologists were blinded to the study hypothesis.

Conclusion

Together with previous studies, our data indicate that there is no single mechanism-related soft tissue injury pattern of simple elbow dislocation and that different grades of soft tissue injury exist.^{12,16,17} This prompts reconsideration of models of injury and the methods of assessment of acute injuries.

Disclaimer

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